Water Balance and Water Conservation in Thermal Power Stations (TPS)

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While we are aware that water is one of the most important resource nature has provided, we give little attention to how we use it. There is no exception when it comes to use in power stations. Cooling methods in thermal power stations are highly water intensive process. A correct evaluation and by applying **a**few adjustments we can save on not only water but **also** on electricity bills.

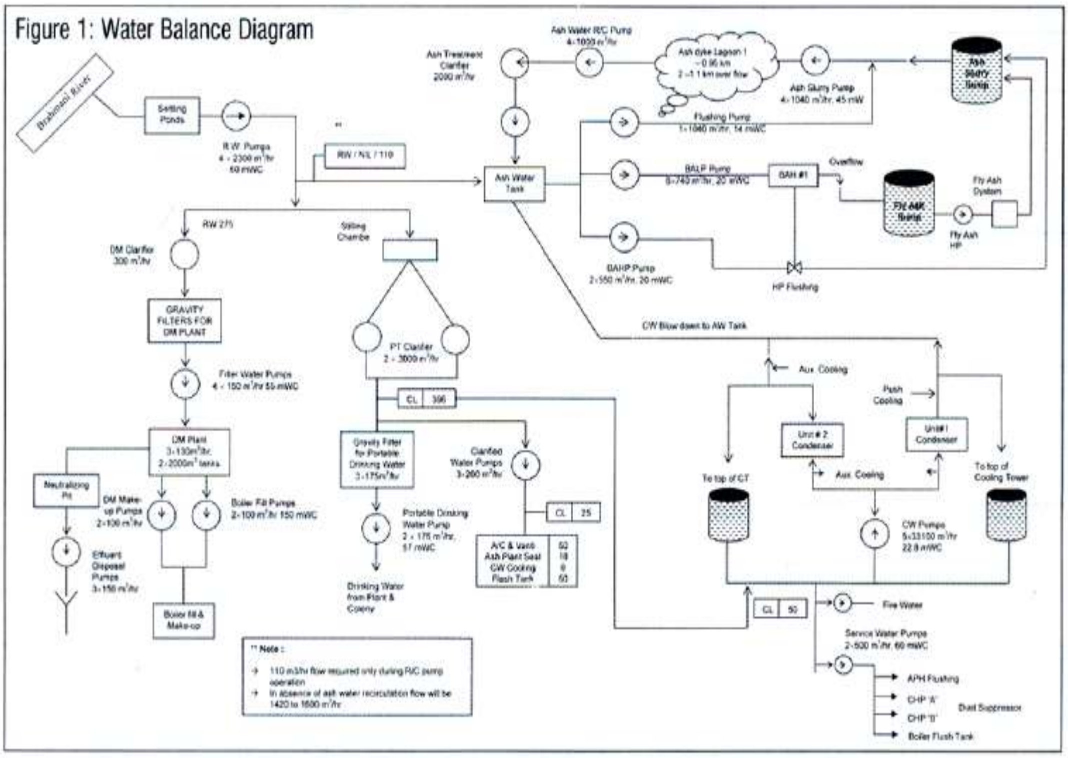
Introduction

In thermal power stations consumption of auxiliary power, specific coal consumption, specific oil consumption and heat rate are generally monitored. Many**,** at the power plants may not know the specific water consumption, except in percentage terms DM water makeup. In the recent past, the water cost has gone up by more than 70 times in many states. A typical super thermal power station of 2100 mW pays around Rs. 12 crore i.e. more than Rs.1 **C**rore/month itself towards water bill for the raw water alone, excluding what is paid to the pollution control boards as cess. There is lot of prudence in monitoring the specific water consumption in terms of M^3/MW or liter/kWh. **(The specific water consumption of coal based power plants varies between 1.7 – 8 liters/kWh.)**-**A**s per Government **of India** directive all the **t**hermal power plants **must**reduce their **s**pecific water consumption to below 3.5 M^3/mWhby December 2017. By systematic water audit, one can reduce water consumption to the tune of 30-40 percent. Water conservation also leads to reduction of auxiliary power consumption, since there is close nexus between water and energy.

Water Circuit in Thermal Power Station (TPS)

In thermal power stations, by quality considerations and end use considerations, water can be classified as: Raw water, clarified water, Drinking water, DM **(De Mineralised)** water, Service water, Ash water, Cooling water, or Circulating water, Fire water, etc. For all these, raw water is the main source. Normally the raw water is sourced from nearby river, irrigation canal or a pond. For handling all these different type**s** of water streams, number of pumps and pumping stations are **employed**. A typical water circuit diagram is presented in the Figure (1).

Fig: 1Typical water balance diagram



Typical Water Balance:

Figure: (2) indicates the typical overall water balance for a super thermal power plant of 2100 mWcapacity. If the power plant has **many** stages, or sections, then the water balance can be done for ‑pump house-wise like raw water pump house, pre-treatment plant, DM plant, ash water pump house, ash slurry pump house, fire water pump house, Effluent Treatment Plant (**ETP)**, etc. By recording water balance, either on hourly basis or daily basis, one can know the losses and identify the reasons for thelosses.

Fig: 2 Water balance for a super thermal power plant

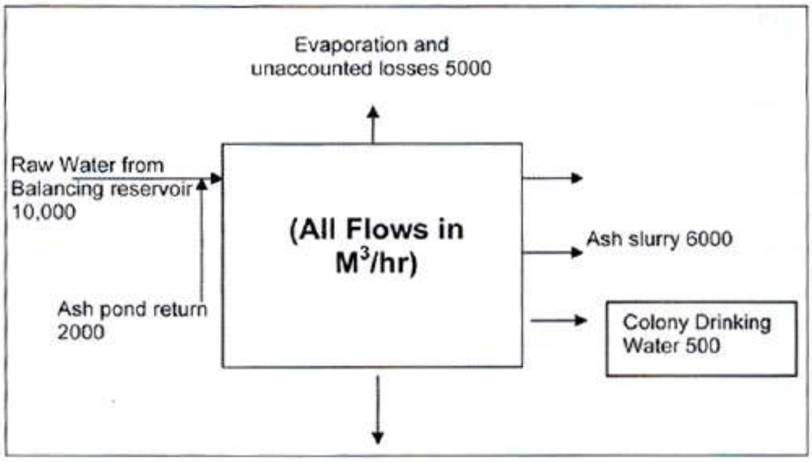


Figure 2: Water balance for a super thermal power plant

Flow Measurements:

For carrying out water balance, water flow measurement is the key. Except for **C**ondensate **E**xtraction pump (CEP) flow and **B**oiler **F**eed Water **P**ump (BFP) flow, one may not find flow meters in the power plants. Only DM water records are normally maintained. For condenser cooling water flow measurement in some of the power plants, annubaris provided. But their accuracy and reliability need to be ascertained. Now-a-days one can use ultrasonic flow meters for a majority of water flow measurements. With ultrasonic flow meters one **must** ensure at least a straight pipe length of 5D in the upstream and 10D lengths in the downstream for a reasonable accuracy of ± 2 percent. The present ultrasonic flow meters have a capability to measure up to 5000 mm diameter. The maximum pipe sizes encountered normally in 210 mW plants is 1600 mm and for 500 mW plants is 2000 mm for the condenser cooling water pipe lines. The other methods used for measuring condenser circulating water flows are tracer method. Even for ash slurry flow measurements, the Doppler Effect **M**eters are available in the market. For open channel flow measurements, one can use either V-notch or turbine flow meters.

By measuring water flow, while **Simul**taneously measuring power consumption and the head developed by the pump, one can calculate even pump efficiencies. By comparing these efficiencies with either **P**erformance **G**uarantee (PG) values or with design figures, one can assess their present condition. For pumps in the power plants which are more than 5 **to**10 years old, one can know the extent of deterioration over a period, by conducting a systematic water audit.

Present Specific Water Consumption:

Specific water consumption is the key indicator for comparing and assessing the performance of different thermal power stations. The specific water consumption can be expressed as M^3/mW or liter/kWh. **Specific water consumption figures vary from 1.7 to 8.0 M3/MW.)** This value mainly depends on the size, age and the type of the plant (either coal based or gas based), type of water circulation (i.e. once through system or cooling tower based), dry ash handling system or wet ash handling system, provision for ash water recycling, etc. Based on a number of water balance studies carried out by Siri Exergy, the specific power consumption figures achieved in several thermal power stations are presented in the table **1** (1).

By systematic water audit and quantifying water **f**lows at each pumping station, one can carry out water balance with a reasonable accuracy

Table **1**: **Typical range of specific water consumption figures of different power plants**

Typical Specific Water Consumption rates for Thermal Power Plants			
Sr no	Power plant type	Power plant rating mW	Range M^3 / mW
1	Gas based power plants		1.7 - 2.0
2	Total dry ash handling power plants		3.0 - 3.5
3	Coal based thermal power plants with once trough system	210	3.0 - 3.5
4	Coal based thermal power plants	210	4.0 - 5.0
5	Coal based power plants with ash water recycling	210	3.5 - 4.5
6	Coal based super thermal power plants	500	3.5 - 4.5
7	Coal based super thermal power plants with ash water recycling	500	3.0 - 4.0
8	Coal based old power plants	110	6.0 - 8.0
9	Coal based old power plants with Air Cooled Condensor (ACC)	10 to 30	1.0 - 1.5

New Specific Water Consumption Norm

As per the new Government**of India** directive all the old Thermal power plants **should**-reduce their specific water consumption in terms of lit/kWh or M^3/mWh has to reduce below 3.5 by December 2017. Where the new plants which are going to be commissioned after January 2017, **have** maintain 2.5 M^3/mWh. The water consumption limits for thermal power plants is presented in following table – (2).

With this new directive, all the thermal power plan**ts** **have** to submit the Water Balance audit reports to Ministry of Environment and Forests (MoEF). The thermal power plants whose specific water consumption is higher than the norm -**must** put lot of efforts in reducing /recycling and take up concrete action plans to conserve water.

Table- (2) **Water consumption limits for thermal power plants**

Industry	Parameter	Standards
Thermal Power Plant (Water consumption limit)	Water consumption	I. All plants with Once Through Cooling (OTC) shall install Cooling Tower (CT) and achieve specific water consumption up to maximum of 3.5m3/MWh within a period of two years from the date of publication of this notification. II. All existing CT-based plants reduce specific water consumption up to maximum of 3.5m3/MWh within a period of two years from the date of publication of this notification. III. New plants to be installed after 1st January 2017 shall have to meet specific water consumption up to maximum of 2.5 m3/MWh and achieve zero waste water discharged.

Typical Break-up of Water Consumption

Table (3) presents the water consumption (in terms of raw water) for various purposes in a typical coal based super thermal power plant of capacity 2100 mW with ash water recycling facility. **A**sh handling consumes the major quantity, to the tune of more than 40 percent, followed by the cooling **towers** (to compensate for evaporation losses). DM water consumption is the only minor quantity to the tune of only 2-2.5 percent in terms of raw water. But many thermal power plants monitor only this consumption. Drinking water consumption is also minor in the plant (1-2 percent), but major quantity goes towards colony. Firefighting water normally will be in the closed loop, so technically there should not be any consumption, but due to leaks and usage towards washing of floors, Coal yard spray etc. the consumption will be around 4-5 percent.

Without ash water recycling, the total raw water consumption would go up by another 2000 M^3 /hr.

Figure (3) depicts the water consumption for various activities in the thermal power plants.

A thermal power plant of 2100 MW capacity recycles approximately 2000 M^3/hr ash water. Reducing water consumption form 5.86 liter/kWh to 4.9 liter/kWh results in reduction of 16 percent in water consumption and savings of Rs.15.8 million/annum in water bill.

Water consumption for ash handling, cooling tower and drinking are significant. Therefore, the scope for water conservation is also significant. The next section deals with the various options for water conservation in the thermal power plants.

Table (3): **Water consumption in a coal based super thermal power plant**

Sr no	Area	Quantity M^3 / hr	Consumption with ash water recycling M^3 / mW	%
1	Ash handling	4180.00	2.00	41.40
2	Cooling towers	3207.00	1.50	30.40
3	DM water	260.00	0.13	2.60
4	Drinking water (colony + plant)	640.00	0.32	6.30
5	Coal handling	130.00	0.07	1.30
6	Fire fighting	476.00	0.37	4.70
7	Others	1334.00	0.66	13.20
8	Total	10009.00	5.00	100.00

Fig: **3 Typical break up of raw water consumption in thermal power plant**

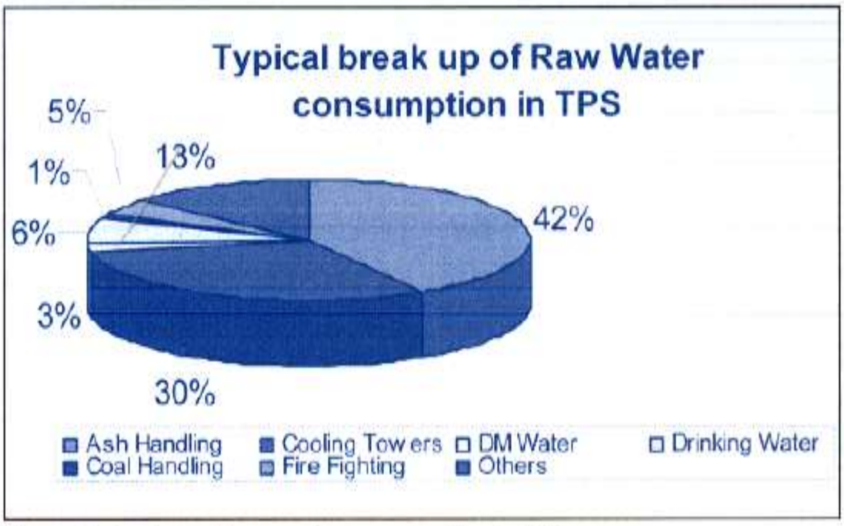


Figure 3: Breakup of raw water consumption in TPS

Water conservation measures

By systematic water audit and quantifying water flows at each pumping station, one can carry out water balance with a reasonable accuracy. By knowing inflows and outflows, the losses or wastage can be quantified and these losses can be optimized by taking appropriate measures. Based on water audit studies in **many** thermal power stations, following are some of the possible options, **available,**which will give major savings both in terms of water and **e**nergy:

Optimizing ash water ratio

In wet ash handling power plants, about 50-60 percent of water is consumed just for ash handling. Either raw water can be used directly for ash handling or the condenser outlet water is tapped for ash water purpose. High pressure ash water is used for flushing both bottom ash/fly ash and trench jetting etc. and low pressure ash water is used for bottom ash hopper filling etc. The bottom ash slurry and fly ash slurry can be either handled separately or together by mixing both of them in a common pit.

The ash slurry is evacuated by a series of ash slurry disposal pumps to an ash dyke to a distance of about 15 kM. Typical design ash water ratios are around 1:5 for fly ash and 1:8 for bottom ash.

However, the actual combined ash water ratios are found to be around1:20 or even more. A typical 210 mW thermal power plant generates about 60 tons of ash/ hr (@40% ash content in the Coal and 0.7 ton / mW specific coal consumption). For every percent reduction of ash water ratio, there is a saving potential of 60 M^3/hr of water. In addition to water savings, the associated auxiliary power consumption reduction would be 0.2 mU/annum for every ash water ratio reduction in the HP/LP ash water pumps and ash slurry series pumps. Normally, the ash water system is designed for catering to the needs of entire stage consisting of 2 to 3 units. So, when any unit in that stage is under **s**hutdown, they will be registering very high ash water ratios. After initiating water conservation measures, many thermal power plants have brought down their ash water ratios to a reasonable level to 1:10 to 1:12.

Recycling ash water from ash dyke

As already mentioned, about 60 percent of water is consumed for ash handling purpose alone. Normally, the ash slurry is sent to ash dykes, which are normally located about 14-15 km away from the main power plant. After the ash gets settled in the ash dyke, the clear water can be recycled. This water can be re-used for ash handling purpose after minor treatment (if necessary). Since many power plants have to shut down or reduce their load, particularly during summer due to the need of sufficient water, the recycling of ash water from the ash dyke would be justified, even if it calls for huge investment. Many power plants have already initiated action towards setting up ash water recycling systems. A thermal power plant of 2100 mW capacity recycles approximately 2000 M^3/hr ash water. By reducing water consumption from 5.86 liter/kWh to 4.9 liter/kWh results in reduction of 16 percent in water consumption and savings of Rs.15.8 million/annum in water bill (@ Rs.1/kL of raw water).

By restricting the water supply timings limited to main water consumption periods such as mornings, noon and evenings etc. and rectifying the float vales of all the overhead tanks, the water consumption can be greatly reduced by more than 30-40 percent

Increasing cycles of concentration (COC)

The maximum water loss in the thermal power plants will be in the cooling towers, in the form of evaporation. We need around 180 M^3/hr cooling water flow to the condenser to generate 1 mW.

Empirical relation often used to calculate evaporation ratio (M^3/hr) =

(circulation rate in M^3/hr x Temperature Difference in ^oC) /675.

Based on this formula, the expected evaporation ratio for every 1mW of power generation is 2.6 M^3/hr. For a 210 mW power plant, the expected evaporation loss would be 550 M^3/hr. To compensate this evaporation loss, the blow down losses and drift, make up water is provided. Since water is circulated many times in the closed loop, the concentration of dissolved solids increases over a period. The cycles of concentration (COC) is the ratio of dissolved solids in the circulating water to the make-up water. Normally the cooling towers are designed for a COC of around 3. To keep -COC of 3, we need to provide a blow down of around 275 M^3/hr, for a 210 mW power plant. Since many thermal power plants face water shortage during summer, by increasing COC, the blow down quantity can be reduced. By external water treatment and adding water treatment chemicals, COC of even 10 can be reached. By increasing COC from 3 to 10, we can reduce the blow down quantity drastically from 275 M3/hr to 30 M^3/hr, which is a savings of 88 percent.

Reducing drinking water consumption

For colony water requirements, water is supplied from the drinking water line of the main plant. Based on number of water balance studies carried out by the authors in different thermal power stations, around 500-600 M^3/hr water is supplied continuously to the colonies. The per capita water consumption works out to 600-800 liters/day/person, which is very high, when compared to WHO norms of 115 liters/ day/person. This indicates tremendous scope for water conservation in the colonies. In fact, water is a luxury in majority of the colonies. This is mainly due to continuous supply and wastages due to lack of awareness. By restricting the water supply timings limited to main water consumption periods, such as mornings, noon and evenings etc. and rectifying the float valves of all the overhead tanks, the water consumption can be greatly reduced by more than 30-40 percent. By installing sewage water treatment plant in the colony and recycling the treated water and using it for gardening purpose, another 10-20 percent precious drinking water can be saved.

Reducing leaks and over flows

Invariably, we find lot of water leaks from Valves, Flanges, Taps, Firefighting hoses, underground firefighting lines, cooling tower basin, gardening hoses etc. Overflows from cooling towers of AC plants, Air washers, and Overhead tanks due to non-functioning of float systems are also a common feature in thermal power plants. Huge water leaks from the condenser pipe ducts were also noticed in some of the plants. By bringing underground firefighting lines to over ground, attending various water leaks, providing ball and cock float systems for overhead tanks and smaller cooling towers, 3-5 percent water consumption can easily be reduced.

Installation of Effluent Treatment Plant (ETP) / STP

A typical thermal power plant will have 3-4 main drains. All this drain water gets collected and finally goes out of the plant boundary. The measured drain quantities alone are found to be in the range of 800-1000 M^3/hr. This is a large quantity. By installing effluent water treatment plants and recycling this water for the ash handling purpose, 80-90 percent of this water can be saved. The drains from the coal handling plant will be blackish due to coal dust. They need to be treated separately by installing additional settling ponds.

By installing **S**ewage **T**reatment **P**lant **(STP)** in the colony also, the treated water can be recycled and can be used for horticulture purposes.

Conclusion

Like any other resource, water availability is also likely to become scarce in the years to come. Many progressive managements have already initiated measures for water conservation in their thermal power plants. It can be seen from the above study that water cost is going up every year including the cess paid to the pollution control boards. Many thermal power plants are reducing their plant load mainly due to water shortage particularly during summer. Now with the new government directive all the thermal power plants must reduce their specific water consumption to below 3.5 M^3/mWh, by December 2017. Those thermal power plants whose specific water consumption is higher than the norm should put lot of efforts in reducing /recycling and take up concrete action plans to conserve water.

Based on the various water audits in different thermal power stations, savings worth Rs.3.3 crore/annum, equivalent to 40 percent water use reduction have been identified as possible. Since there is a close nexus between water and energy, energy savings to the tune of 3.57 Mu/annum is also identified by adopting various water conservation measures. Monitoring specific water consumption is the key for success in achieving water conservation.